

METHOD AND APPARATUS FOR ESTABLISHING DIRECT COMMUNICATION FOR MOBILES IN A RADIO COMMUNICATION SYSTEM

BACKGROUND

5 The present invention relates generally to radiotelephone systems. More particularly, the present invention relates to methods and apparatus for establishing direct communication among physically close mobile stations in a radiotelephone system using Opportunity Driven Multiple Access protocol.

10 A variety of radiotelephone systems have been developed for providing communication service between mobile stations and base stations. Radiotelephone systems generally include cellular telephone systems, personal communication systems (PCS), trunked radio systems and other similar radio systems. In such a system, one or more base stations provide two-way radio communication service to mobile stations operated by subscribers and located in
15 the geographic area served by the base station. As a mobile station is powered up or newly moves into a base station's coverage area, the mobile station registers with the base station, including identifying itself and its capabilities. As a mobile station moves among geographic areas, communication between the mobile station and a base station is handed off to other base stations. Such systems typically also
20 include a mobile switching center to control handoff operations and traffic routing in the system.

 Radiotelephone systems permit radio communication of voice and data between mobile stations and between mobile stations and the public switched telephone network. However, mobile-to-mobile communications have heretofore
25 been completed through a base station. To initiate a call to another mobile station in the system, a calling subscriber at an originating mobile station initiates a radio link with its serving base station, which is generally the geographically closest base station. The originating mobile station sends a call request to the base station. The call request includes identification information such as a mobile
30 identification number for the called mobile station, or terminating mobile station.

The base station then locates the terminating mobile station in the system. The base station may consult with the mobile switching center to learn with which base station the terminating mobile station last registered. If the terminating mobile station is registered with the base station itself, the base station sends a
5 page to the terminating mobile station. The page is a radio communication with predetermined timing and content inviting the terminating mobile station to respond to begin two-way communication. The terminating mobile station then responds and the base station completes the call between the calling subscriber at the originating mobile station and the called subscriber at the terminating mobile
10 station. Typically, either the calling subscriber or the called subscriber or both are billed for the time during which the call is underway.

In current systems, this process is followed even if the two mobile stations are in close physical proximity, close enough for reliable radio contact. The two-way communication between the two mobile stations requires two two-way radio
15 links. A first link is maintained between the originating mobile station and the base station. A second link is maintained between the base station and the terminating mobile station.

In cases where mobile stations are physically close together, this is wasteful of system resources. If direct mobile to mobile communication was
20 possible, the two base station radio links would be freed up for use by other mobiles, improving utilization of system resources. Moreover, the mobiles could operate at reduced transmit power, reducing radio frequency noise in the system for other base stations and other mobiles. Still further, since system resource usage is reduced by removing the base station from the communication link,
25 alternative pricing options could be offered for subscribers.

Accordingly, there is a need for improved method and apparatus for mobile to mobile communication in a radiotelephone system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a radiotelephone system; and

FIGS. 2 and 3 are flow diagrams illustrating a method of operating the radiotelephone system of FIG. 1.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

5 Referring now to the drawing, FIG. 1 is a block diagram of a radiotelephone system 100. The radiotelephone system may be any cellular system, personal communications system, trunked radio system or any other type of radio system. In an exemplary embodiment, the radiotelephone system 100 is a
10 Universal Mobile Telecommunications System (UMTS) as specified by the Third Generation Partnership Project. Radio communication in the exemplary radiotelephone system is selectively time division duplex (TDD) and frequency division duplex (FDD). The radiotelephone system 100 is an example of a public land mobile network (PLMN).

15 The radiotelephone system 100 includes a plurality of base stations 102, 104, and a plurality of mobile stations. Each base station 102, 104 provides radio communication service to mobile stations in the geographic vicinity of the base station. Thus, in the embodiment of FIG. 1, base station 102 provides radio communication service to mobile stations 106, 108, 110 and base station 104 provides radio communication service to mobile stations 112, 114. A two-way
20 radio link is established between a mobile station and one or more base stations. As a mobile station enters the area served by the base station, the mobile station registers with the base station, so that the mobile station may be locate for paging. As mobile stations move geographically, radio communication is handed off from base station to base station. The system 100 may further include a mobile
25 switching center for controlling system-level operations such as handoff.

Mobile station 110 illustrates an exemplary embodiment of a mobile station of the system 100. The mobile station 110 may also be referred to as a mobile, portable, handheld, user equipment (UE) or radiotelephone. The mobile station 110 includes an antenna 120, a receiver 122, a transmitter 124, a controller 126,
30 memory 128, user interface 130 and battery 132.

The antenna 120 transforms electromagnetic energy to electrical signals provided to the receiver 122, and transforms electrical signals from the transmitter 122 to electromagnetic energy for transmission to remote radio receivers. The receiver 122 responds to the electrical signals from the antenna 120 to produce
5 detected data for the controller 126. The receiver 122 may include circuits such as filters and demodulators. The transmitter 124 responds to formatted data from the controller to provide the electrical signals to drive the antenna 120. The transmitter 124 may include circuits such as modulators and filter. The antenna 120, the receiver 122 and the transmitter 124 together form a radio communication
10 circuit for two-way radio communication with remote radio devices such as the base station 102.

The controller 126 controls operation of the radiotelephone 110. The controller 126 may be implemented as a processor, microprocessor, digital signal processor (DSP) or any other logic circuit or combination of circuits providing
15 control functions. The controller 126 operates in response to data and program instructions stored in the memory 128. In one mode, the controller 126 controls the radio communication circuit by directing the tuning, activation and deactivation of the circuit. The user interface 130 provides user control of the radiotelephone 110. In typical embodiments, the user interface 130 includes a
20 keypad, a display screen, a microphone and a speaker. The battery 132 provides operating power for the radiotelephone 110.

In accordance with the presently disclosed embodiment, the mobile stations including the mobile station 110 can operate in a variety of modes. One mode is idle mode. When a mobile station such as the mobile station 110 is switched on, it
25 attempts to make contact with a public land mobile network (PLMN) such as the radiotelephone system 100. The mobile station looks for a suitable cell of the chosen PLMN and chooses that cell to provide available services, and tunes to its control channel. This choosing is known as "camping on the cell," and the mobile station is operating in idle mode. The mobile station will then register its
30 presence, by means of a registration procedure, in the registration area of the chosen cell, if necessary.

In another operating mode, the mobile stations including the mobile station 110 may operate in a connected mode. In this mode, an active two-way radio link is maintained between the mobile station and one or more base stations. Voice and data transmission can occur and handoff can occur if the mobile stations travel among the geographic areas served by the base stations. In a UMTS-FDD system, idle mode and connected mode correspond to FDD operation. TDD is also part of UMTS.

Another operating mode for the mobile stations is relay mode. In this mode, the mobile station communicates directly with other mobile stations. The mobile station operates as a repeater, receiving radio signals from a data source and relaying the radio signals to a radio destination. Any number of mobile stations may be chained together in this manner.

One example of a specification for a UMTS radio operating in relay mode is known as Opportunity Driven Multiple Access (ODMA). An ODMA mobile station communicates via its neighbors using intelligent subscriber relay. A fundamental of the ODMA philosophy is that communications is considered as a dynamic, localized activity best controlled at node level, rather than from some centralized intelligence such as a base station or mobile switching center.

The choice of modulation scheme is not critical to ODMA. Transmission is completely packet based and connectionless and each mobile station is able to relay packets from its neighbors. Furthermore, a mobile station will adapt on a packet by packet basis its transmission route, power, data rate, packet length, frequency, time window and voice quality over a wide dynamic range.

Each mobile station in ODMA has responsibility and, to a large degree, autonomy for local routing and optimal adaptation to the communication environment, although it will accept the authority of a network supervisor such as a base station or mobile switching center.

When in the ODMA mode, the mobile station initiates or continues to evaluate the relay link to other radios via a process known as probing. Probing is a mechanism used by the ODMA relay node to build a neighbor list which should contain at least a minimum number of neighbors. The probing activity levels of an

ODMA relay node may also be influenced by a number of system parameters such as the number of neighbors, gradient information and path loss to neighbors.

5 In accordance with one embodiment of the radiotelephone system 100, mobile stations detect possible relay candidates and report on these to the base station. The detection is preferably in accordance with the ODMA probing process, but other monitoring techniques. For example, the mobile station could monitor uplink transmissions from adjacent mobiles. The uplink is the radio link for transmission from the mobile station to the base station. Detected relay candidates are added to a relay candidate list. From time to time, information
10 about the relay candidate list is transmitted to the base station, for example, in a process that is similar to handover candidate reporting.

In order to better utilize system resources, the present embodiment provides for detecting if mobile stations which are trying to establish communication with each other are physically close to each other. If so, the ODMA protocol or another
15 relay mode may be used to establish direct communication between the mobile stations.

Thus, a mobile station M1 requests communication with a mobile station M2. The mobile station M1 transmits a request to its serving base station identifying mobile station M2 as a target. From the relay candidate list reported
20 by mobile station M1, the base station detects that mobile stations M1 and M2 are physically close together and instructs them to establish direct communications.

In accordance with this embodiment, the mobile stations such as mobile station 110 are adapted for communication both in idle and connected modes with a remote base station, and in relay mode with other mobile stations or a base
25 station or other radios. The radio communication circuit of the mobile station is configured for two-way radio communication with remote radio devices, such as base stations and other radios acting as repeaters in relay mode. The controller 126 is configured to control the radio circuit. First, the controller controls the radio circuit to establish a radio link to a remote base station and convey a request
30 for communication with another mobile station or radiotelephone. The radio circuit receives over the radio link a direct communication instruction, instructing

the mobile station to enter the relay mode. The controller 126 then controls the radio communication circuit to interrupt the radio link to the remote base station and establish a relay radio link with the target mobile station.

In another embodiment, the base station will instruct the first mobile station and the second mobile station to establish direct communication if the radio propagation conditions between the first mobile station and the second mobile station are sufficiently good for direct communication. The base station may obtain information about the radio propagation conditions from any suitable source, such as receiving updates about the radio propagation conditions from the first or second mobile stations or both mobile stations, or by using the relay candidate lists of one or both mobile stations. The mobile stations can use any suitable signal quality evaluation technique, such as received signal strength indication, signal to noise ratio or bit error rate to determine if propagation conditions are sufficiently good between the first mobile station and the second mobile station.

FIG. 2 is a flow diagram illustrating a method of operating the radiotelephone system 100 of FIG. 1. FIG. 2 illustrates interaction between a mobile station M1 and its associated base station BS. Operation at the mobile station M1 begins at block 200. At block 202, the mobile station M1 detects possible relay candidates. At block 204, the detected candidates are added to a relay candidate list, stored, for example, in the memory of the mobile station M1.

In one embodiment, detecting possible relay candidates is accomplished by the ODMA probing process, as the mobile station populates its neighbor list of mobiles in relay communication with the mobile station. In other embodiments, the mobile station M1 can monitor uplink transmissions from adjacent mobiles and measure parameters of such transmissions, such as received signal strength. The decision to add a mobile to the candidate list is based on parameters exceeding predetermined threshold values. In general, the decision to add a mobile to the candidate list reflects a determination that the radio propagation conditions between the mobile stations are sufficiently good for direct communication. Any suitable information about the detected mobile station may

be stored in the relay candidate list. One example is the mobile identity number which uniquely identifies the transmitting mobile station.

At block 206, the mobile station reports its relay candidate list to the base station BS. In some embodiments, reporting the relay candidate list may include
5 or be replaced by reporting on the radio propagation conditions between the mobile stations and other mobile stations. The report may simply be an indication that radio propagation conditions are sufficiently good for direct communication between the first mobile station and another specified mobile station. The presence of another mobile station on the relay candidate list may imply that
10 conditions are sufficiently good. Operation at the base station BS begins at block 210 and at block 212, the base station BS receives the relay candidate list. The relay candidate list is communicated from the mobile station M1 to the base station by establishing a two-way radio link. In a UMTS-FDD, this is done in FDD mode, with the mobile station M1 communicating on an uplink frequency
15 band and the base station BS communicating on a downlink frequency band.

At block 214, the base station BS stores the received relay candidate list from the mobile station M1. The BS conventionally includes a large memory for storing data related to system operation. Stored data includes relay candidate lists and handoff candidate lists from mobile stations in the geographic area served by
20 the base station. At block 216, control proceeds to block 300, FIG. 3, labeled initiate call.

FIG. 3 is a flow diagram illustrating operation of the radiotelephone system of FIG. 1. FIG. 3 illustrates interaction among a first mobile station M1, a second mobile station M2 and a base station M2. After the relay candidate list of the
25 mobile station M1 is sent to the base station BS, for example as described above in conjunction with FIG. 2, control begins at block 300.

At block 304, the mobile station M1 requests communication with mobile station M2. This is accomplished by mobile station M1 establishing a two-way radio link with the base station BS. For example, the mobile station M1 may
30 transmit identification information and a request to initiate a call, identifying its own mobile identification number and the mobile identification number of the

second mobile station M2. This request is received at the base station BS at block 304. An acknowledgement may be sent in return.

At block 306, the base station determines if the mobile station M1 and the mobile station M2 may enter direct communication. This may be done by
5 determining if the first mobile station M1 and the second mobile station M2 are physically close together. This in turn may be done in any suitable manner. In one embodiment, the base station BS retrieves the relay candidate lists for both mobile station M1 and mobile station M2. If the relay candidate list for first
10 mobile station M1 lists second mobile station M2, the first mobile station M1 has recently detected a transmission from the second mobile station M2. Similarly, if the relay candidate list for second mobile station M2 lists first mobile station M1, the second mobile station M2 has recently detected a transmission from the first mobile station M1. In this case, the relay candidate lists are mutually inclusive, and the base station BS may determine that the two mobile stations M1, M2 are
15 physically close together.

In contrast, if the relay candidate list for first mobile station M1 does not list the second mobile station M2, the first mobile station M1 has not recently detected a transmission from the second mobile station M2. Similarly, if the relay candidate list for the second mobile station M2 does not list first mobile station
20 M1, the second mobile station M2 has not recently detected a transmission from the first mobile station M1. In this case, the relay candidate lists are mutually exclusive, and the base station BS may determine that the two mobile stations M1, M2 are not physically close together.

For the intermediate case, where the base station BS determines that the
25 relay candidate list of only one mobile station includes the other mobile station, the result is indeterminate. The base station BS may review other parameters or may decide that the two mobile stations are not physically close together.

As indicated, other proximity tests may be used. In some systems, precise location information is available, such as where mobile stations are equipped with
30 Global Positioning System (GPS) receivers or where the base stations of the system perform some sort of triangulation or time of flight estimate of mobile

position. In this case, the base station compares the geographic data, determines a separation distance or by some other convenient measure, determines if the two mobile stations are physically close.

Another proximity test may simply involve a determination if the mobile stations M1, M2 are in the same cellular coverage sector of the base station BS. That information is available from registration information obtained when the mobile stations last registered with the base station and the system. If the mobile stations are in the same sector, the base station may determine that the two mobile stations are physically close.

Another way for the base station BS to determine if the mobile stations M1, M2 may be placed in direct communication is for the base station BS to determine if the radio propagation conditions between the base stations M1, M2 are sufficiently good. This may be done, for example, by using information reported by one or both of the mobile stations about the current radio propagation conditions, or by reference to the relay candidate lists of one or both mobile stations.

If, at block 306, the base station BS determines that the mobile stations M1, M2 are not physically close, the base station BS will page the second mobile station in the conventional fashion. The base station BS will consult the location register or other system resource defining the last registered location for the second mobile station M2. The mobile station M2 will be paged at that location and, if it answers the page, the call will be routed to mobile station M2. A radio link will be established from the base station BS or other serving base station of the network and the call will be completed. In that case, a first two-way radio link will be established during the call from the first mobile station M1 to the base station BS and a second two-way radio link will be established during the call from the serving base station to the second mobile station M2.

On the other hand, if at block 306, the base station determines that the mobile stations M1, M2 are physically close or that radio propagation conditions are sufficiently good, the base station BS will instruct the first mobile station M1 and the second mobile station M2 to establish direct communication. In one

embodiment, this is accomplished by initiating a first communication link between the base station BS and the first mobile station M1 and communicating a direct communication instruction to the first mobile station M1. The first mobile station M1 receives the direct communication instruction at block 310. This is further
5 accomplished by initiating a second communication link between the base station BS and the second mobile station M2 and communicating a direct communication instruction to the second mobile station M2. The second mobile station M2 receives the direct communication instruction at block 312. After communicating the direct communication instruction, the base station BS
10 terminates the first communication link and the second communication link, freeing up the base station resources required for maintaining those radio links.

The direct communication instruction may be any suitable data or other information required to cause the mobile stations M1, M2 to communicate directly. For example, the direct communication instruction may define the other
15 mobile station involved in the direct communication session by mobile identification number and may further define the direct communication session by frequency and time slot assignments and some priority between the two mobiles.

In the embodiment of FIG. 3, at block 314, the first mobile station M1 contacts the second mobile station M2 directly. This may be done using ODMA relay protocol, where available, or using any other convenient mobile-to-mobile
20 communication scheme. At blocks 316, 316, the two mobile stations continue their direct communication session. In an ODMA environment, a connectionless, packet oriented communication session is maintained. If the direct relay communication is a voice telephone call, the two mobile stations may allocate
25 their resources so that the conversation is clearly conveyed even in the packet-oriented environment. For example, other relay operations with other mobiles station may be discontinued or forbidden during the call.

Subsequent to initiation of the call in the relay mode between the first mobile station M1 and the second mobile station M2, it may become necessary to
30 hand off the call from the relay mode to connected mode. In this case, one or both of the mobile stations will generate a handoff request and transmit the handoff

request to the base station BS. In this case, the base station BS must resume normal cellular communications with both mobile stations. Therefore, the base station BS initiates a first radio link with the first mobile station M1, entering the connected mode with the first mobile station M1, and the base station BS initiates a second radio link with the second mobile station M2. The base station BS then connects the call over the first radio link and the second radio link.

From the foregoing, it can be seen that the present embodiments provide an improved method for direct mobile-to-mobile communication. Mobile stations possessing a relay capability such as that provided by the Opportunity Directed Multiple Access protocol establish a direct link under supervision of the base station, but without continuous access to base station resources. Therefore, this technique can save downlink resources, since the base station is only involved in instructing the mobiles to go into direct communications mode. Moreover, direct communications between mobiles can be low power, thus conserving battery power in the mobile station. Still further, there may be user billing advantages if the network operator offers the direct communications mode as a lower cost option to standard cellular, connected mode communications.

While a particular embodiment of the present invention has been shown and described, modifications may be made. For example, if the two mobiles are in general proximity but not in absolute proximity, the base station may enlist other intervening mobiles as repeaters between the two endpoint mobile stations. It is therefore intended in the appended claims to cover such changes and modifications which follow in the true spirit and scope of the invention.